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(54) LAMINATED TYPE INDUCTOR

(75) Inventors: **Tadashi Tanaka**, Tekefu (JP); **Hiromichi Tokuda**, Takefu (JP)

(73) Assignee: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

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(30) **Foreign Application Priority Data**

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(52) **U.S. Cl.** **336/83**; 336/200; 336/183
(58) **Field of Search** 336/65, 83, 183, 336/200, 232, 223; 257/531; 29/602.1

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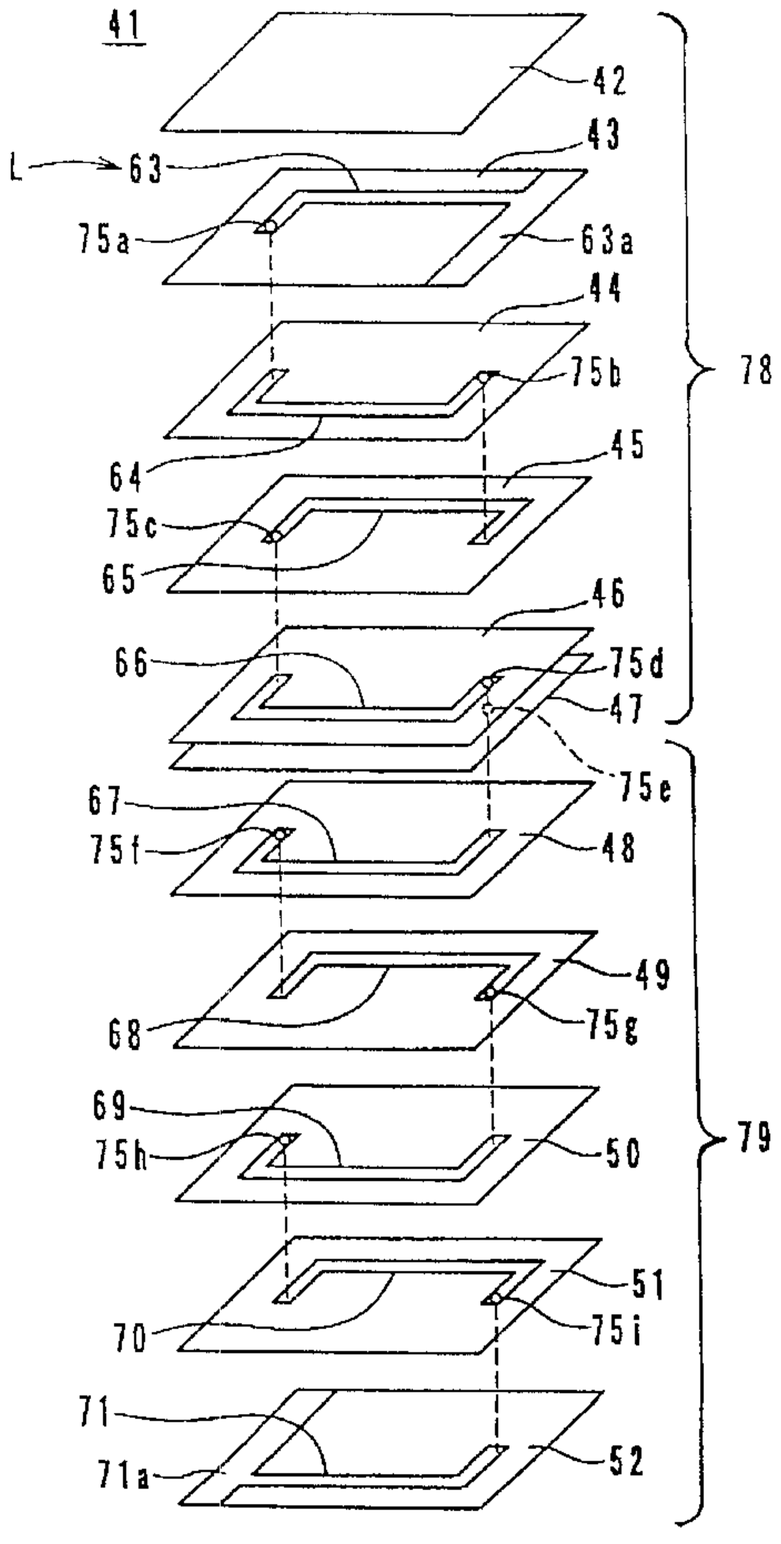
Primary Examiner—Lincoln Donovan
Assistant Examiner—Tuyen T. Nguyen
(74) *Attorney, Agent, or Firm*—Keating & Bennett, LLP

(57) **ABSTRACT**

A small-sized laminated inductor made via a simple firing process includes insulating magnetic sheets made of high permeability materials in which first coil conductors are provided on the surfaces thereof, insulating magnetic sheets made of low permeability materials in which second coil conductors are provided on the surfaces thereof, and other suitable materials. The first and second coil conductors are electrically connected in series through via holes provided in the magnetic sheets to define a spiral coil. In the spiral coil, the first coil conductors are wound in the counter-clockwise direction, while the second coil conductors are wound in the clockwise direction.

10 Claims, 3 Drawing Sheets



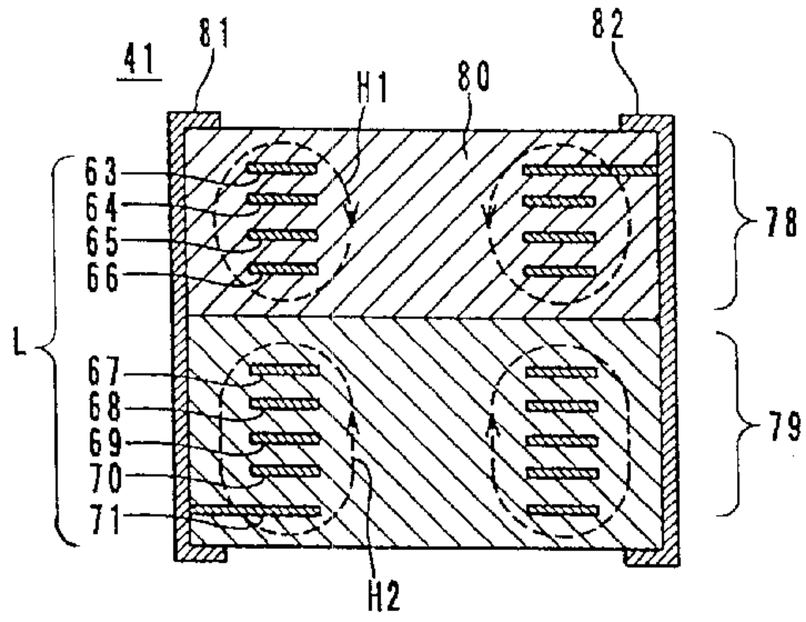


Fig. 1

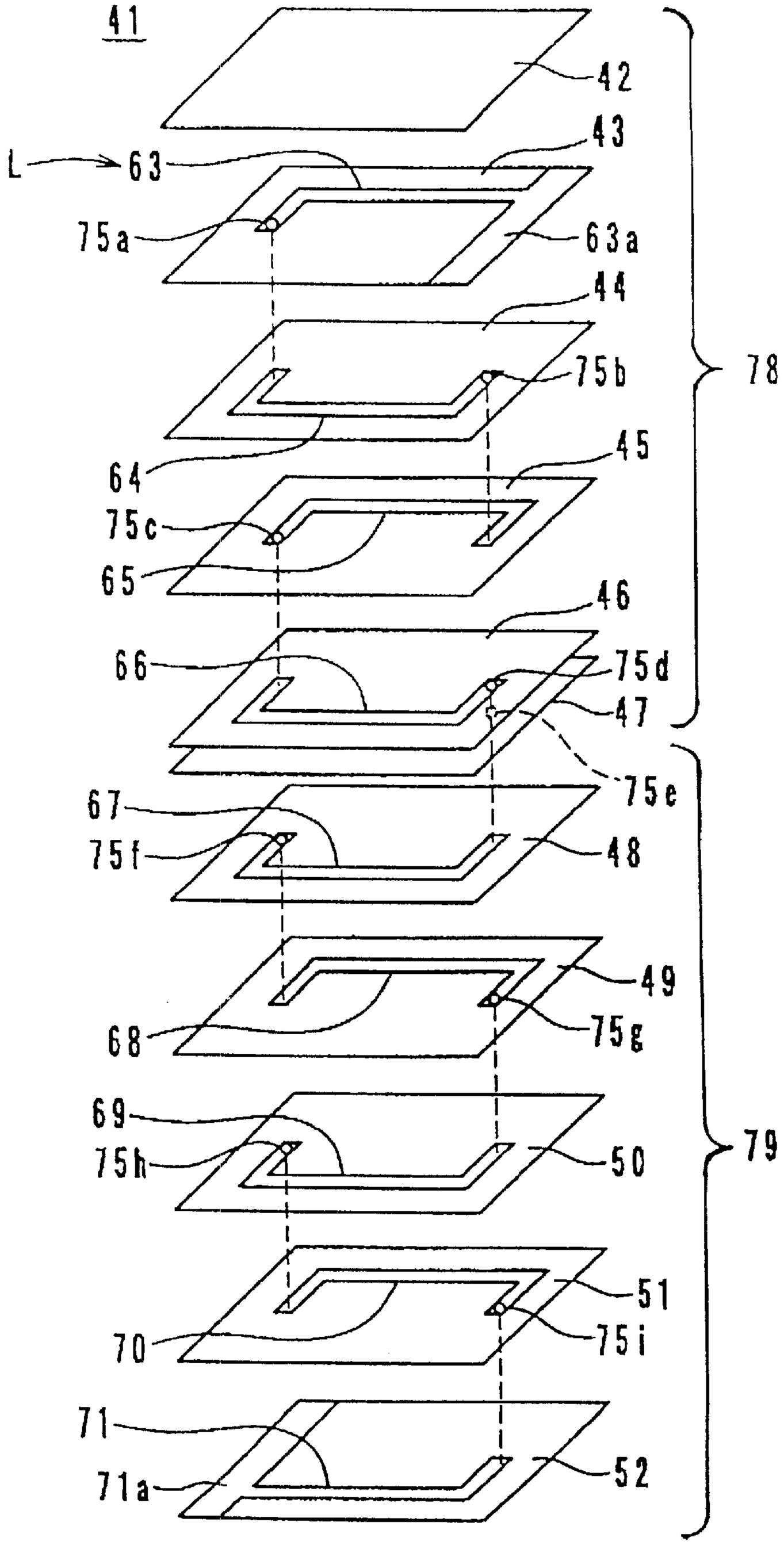

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Fig. 2

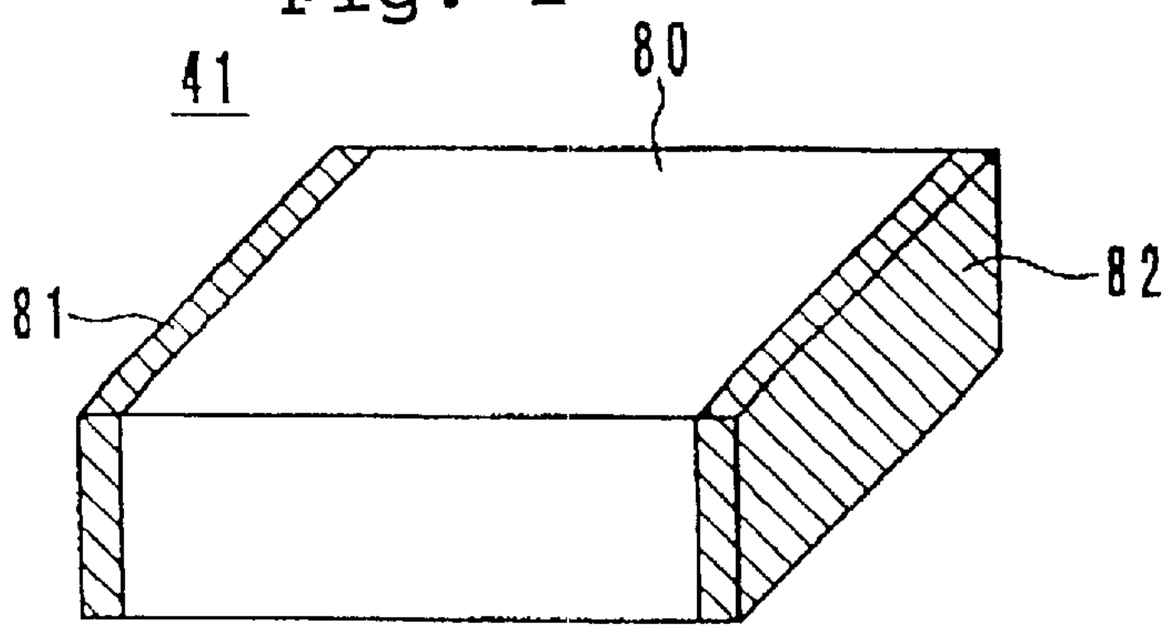


Fig. 3

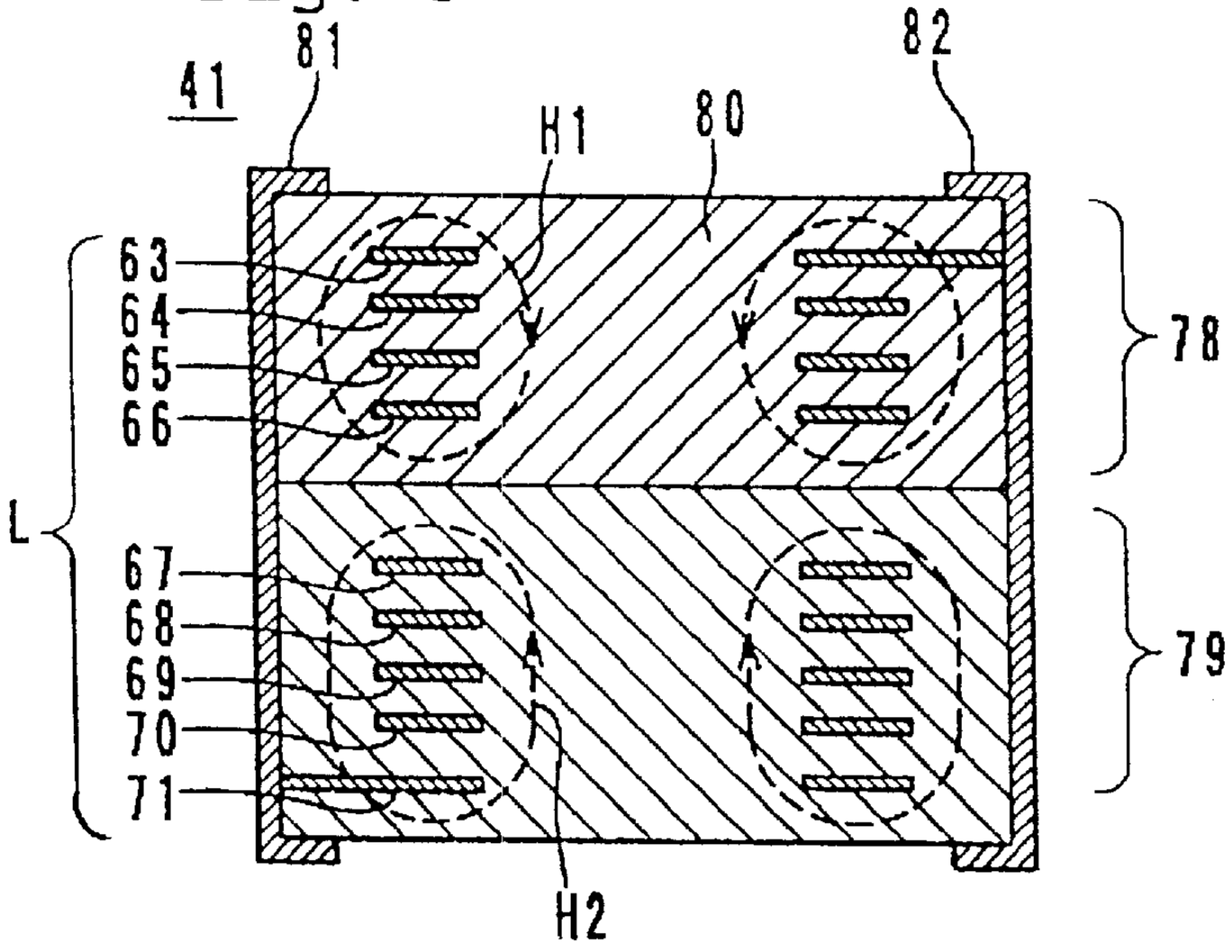


Fig. 4

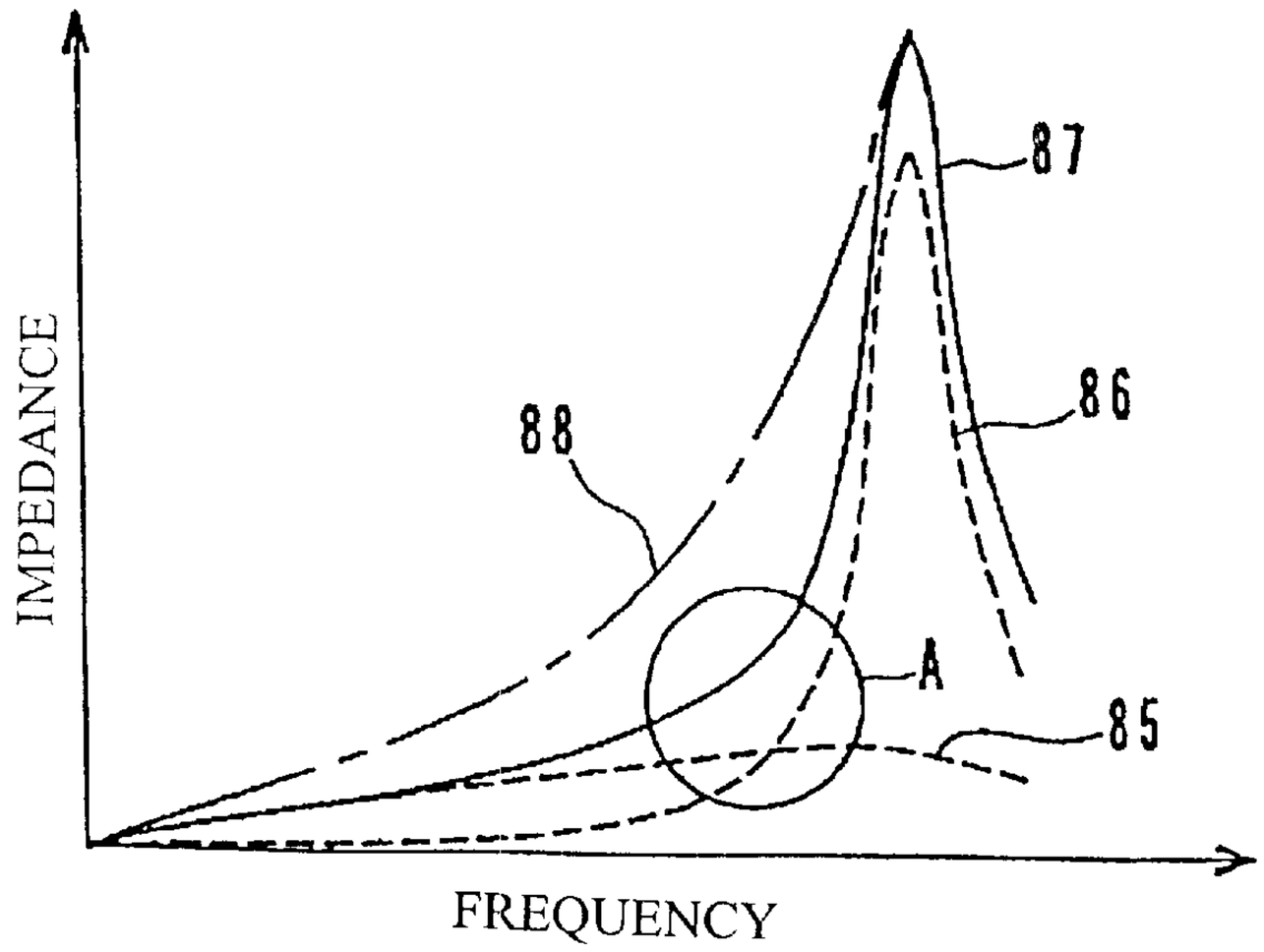


Fig. 5
PRIOR ART

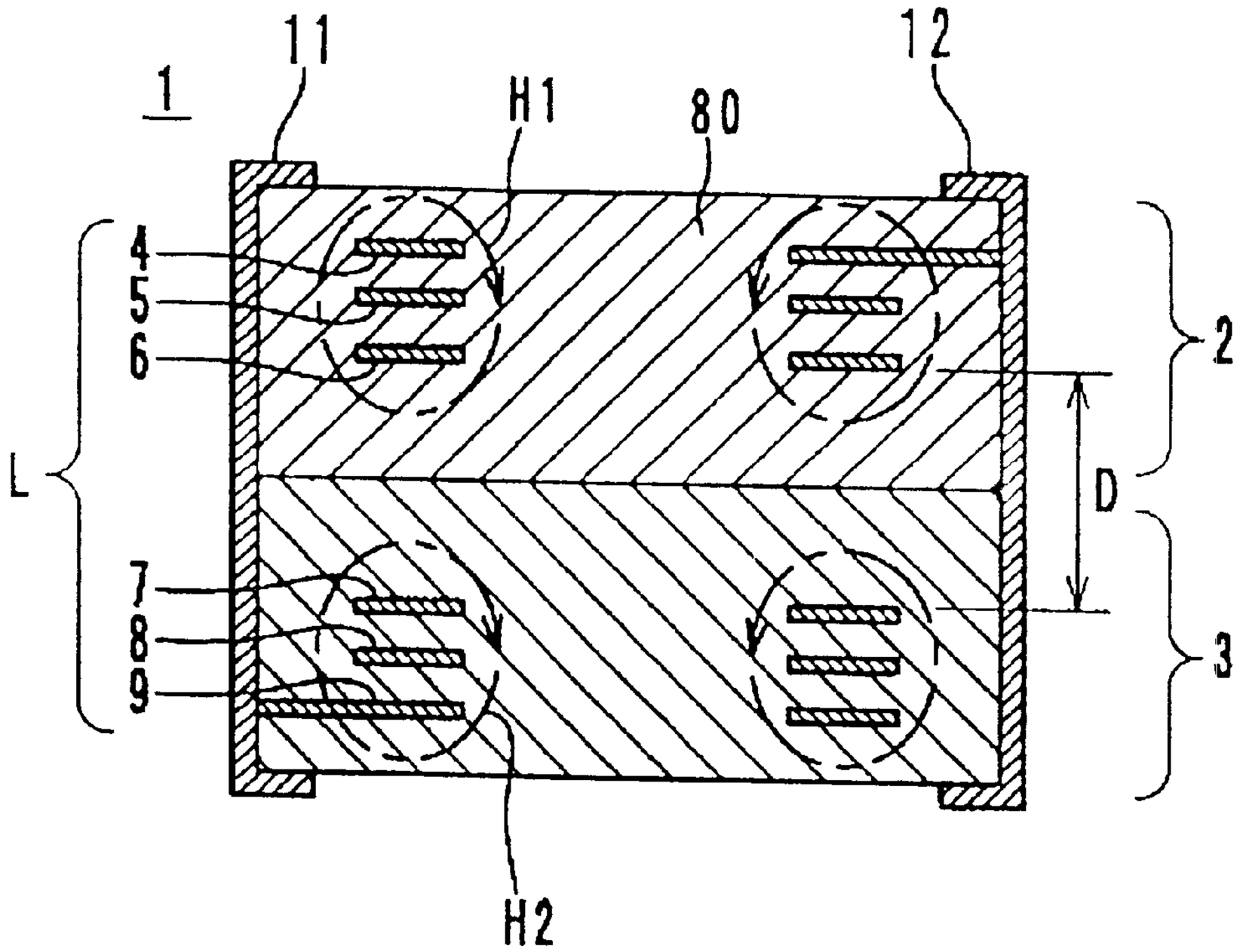
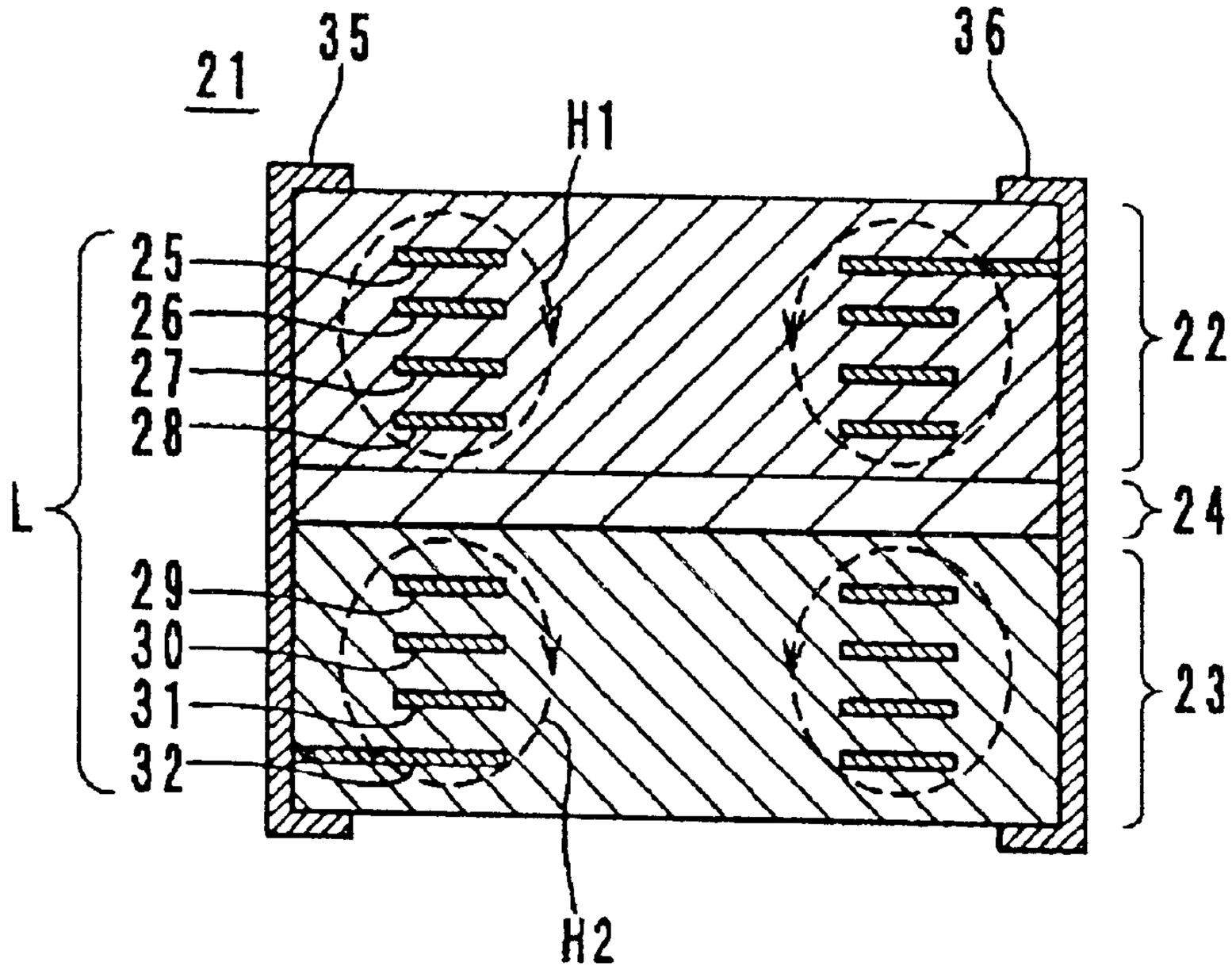


Fig. 6
PRIOR ART



LAMINATED TYPE INDUCTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a laminated type inductor, more particularly, to a laminated type inductor used as a noise filter, and other suitable devices.

2. Description of the Related Art

Generally, when a laminated type inductor is used as a noise filter for a high-frequency signal line, low permeability material is used for a magnetic-substance layer. However, the laminated type inductor made of low permeability material has a problem in that it is easy to generate a link in the waveform of the high-frequency signal.

As a countermeasure, a conventional laminated type inductor **1** is shown in FIG. **5**. The laminated type inductor **1** is constructed such that a high permeability coil section **2** including magnetic-substance layers made of high permeability materials, and a low permeability coil section **3** including magnetic-substance layers made of low permeability materials are laminated and integrally fired. Coil conductors **4–6** in the high permeability coil section **2** and coil conductors **7–9** in the low permeability coil section **3** are electrically connected in series through via holes (not illustrated) to define a spiral coil L. One end (coil conductor **9**) of the spiral coil L is connected to an external electrode **11**. The other end (coil conductor **4**) thereof is connected to an external electrode **12**.

Moreover, a laminated type inductor **21** is also shown in FIG. **6**. A laminated type inductor **21** is constructed such that a high permeability coil section **22** including magnetic-substance layers made of high permeability materials, a low permeability coil section **23** including magnetic-substance layers made of low permeability materials, and an intermediate section **24** made of a non-magnetic material which is disposed between the coil sections **23** and **24** are laminated and integrally fired. Coil conductors **25–28** arranged in the high permeability coil section **22** and coil conductors **29–32** arranged in the low permeability coil section **23** are electrically connected in series through via holes (not illustrated) to define a spiral coil L.

In the conventional laminated type inductors **1** and **21**, when the magnetic field H1 generated in the high permeability coil sections **2** and **22** and the magnetic field H2 generated in the low permeability coil sections **3** and **23** cause mutual interference, the noise suppressing effect is insufficient. To prevent the mutual interference of the magnetic fields H1 and H2, the laminated type inductor **1** shown in FIG. **5** has a large distance D between the coil conductors **4–6** of the high permeability coil section **2**, and the coil conductors **7–9** of the low permeability coil section **3**. However, as the distance D increases, the size of the laminated type inductor **1** also increases.

On the other hand, in the laminated type inductor **21** shown in FIG. **6** the intermediate section **24** is located between the high permeability coil section **22** and the low permeability coil section **233***gv* to prevent the mutual interference of magnetic fields H1 and H2. However, it is technically difficult to accomplish integrally baking both the magnetic material for the coil sections **22** and **23**, and the dielectric material for the intermediate section **24**, because the physical structure and the rate of heat-shrinking of both are substantially different. Thus, controlling the manufacturing processes is complicated.

SUMMARY OF THE INVENTION

To overcome the above-described problems, preferred embodiments of the present invention provide a small-sized laminated inductor with a substantially simplified baking process.

According to preferred embodiments of the present invention, a laminated type inductor including a low permeability coil section in which magnetic layers made of a relatively low permeability material and coil conductors are laminated, and a high permeability coil section in which magnetic layers made of a relatively high permeability material and coil conductors are laminated, the low permeability coil section and the high permeability coil section are laminated such that the coil conductors of the low permeability coil section and the coil conductors of the high permeability coil section are electrically connected in series to define a spiral coil, and the winding direction of the coil conductors in the low permeability coil section and the winding direction of the coil conductors in the high permeability coil section are opposite to each other.

When the low permeability coil section and the high permeability coil section are bonded together, since both of them are made of magnetic materials without using a different material, bonding reliability is substantially improved.

Moreover, since the winding direction of the coil conductors in the low permeability coil section and the winding direction of the coil conductors in the high permeability coil section are arranged in the opposite direction, mutual interference of the magnetic field produced in the low permeability coil section and the magnetic field produced in the high permeability coil section is prevented.

Other features, elements, characteristics and advantages of the present invention will become apparent from the following description of preferred embodiments thereof with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view showing a preferred embodiment of a laminated type inductor according to the present invention.

FIG. **2** is a perspective view of the laminated type inductor shown in FIG. **1**.

FIG. **3** is a schematic sectional view of the laminated type inductor shown in FIG. **2**.

FIG. **4** is a graph showing the impedance characteristic of the laminated type inductor shown in FIG. **2**.

FIG. **5** is a schematic sectional view showing a conventional laminated type inductor.

FIG. **6** is a schematic sectional view showing another conventional laminated type inductor.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereafter, preferred embodiments of the laminated type inductor according to the present invention are explained with reference to accompanying drawings.

As shown in FIG. **1**, a laminated type inductor **41** includes insulating magnetic sheets **43–46** made of high permeability materials in which coil conductors **63**, **64**, **65**, and **66** are respectively provided on the surfaces thereof, and insulating magnetic sheets **48–52** made of low permeability materials in which coil conductors **67**, **68**, **69**, **70**, and **71** are respectively provided on the surfaces thereof, and other suitable

materials. The magnetic sheets **42–46** are produced, for example, such that insulating paste containing ferrite powder of high permeability is formed as a sheet. Similarly, the magnetic sheets **47–52** are produced, for example, such that insulating paste containing ferrite powder of low permeability is formed as a sheet.

The coil conductors **63–71** are electrically connected in series through via holes **75***a*–**75***i* respectively provided in the magnetic sheets **43–51** to define a spiral coil L. In the spiral coil L, the coil conductors **63–66** are wound in the counterclockwise direction, while the coil conductors **67–71** are wound in the clockwise direction. A lead terminal **63***a* of the coil conductor **63** is exposed to the right side of the magnetic sheet **43**. A lead terminal **71***a* of the coil conductor **71** is exposed to the left side of the magnetic sheet **52**.

The above magnetic sheets **42–52**, as shown in FIG. **1**, are laminated in sequence, compressed to be bonded together, and baked integrally. Then the multilayer body **80** as shown in FIG. **2** is produced. Since each sheet **42–52** is made of magnetic material, the bonding property is greatly improved, as compared with the case where the different kinds of material are bonded in the conventional laminated type inductor **21** shown in FIG. **6**.

External electrodes **81** and **82** are respectively provided on the right and left end surfaces of the multilayer body **80**. The lead terminal **63***a* of the coil conductor **63** is connected to the external electrode **82**. The lead terminal **71***a* of the coil conductor **71** is connected to the external electrode **81**.

As shown in FIG. **3**, in the laminated type inductor **41** both the high permeability coil section **78** in which the magnetic sheets **42–46** of the relatively high permeability are laminated, and the low permeability coil section **79** in which the magnetic sheets **47–52** of the low permeability are laminated are stacked directly upon one another without interposing the intermediate section made of dielectric material therebetween. Since the intermediate section is not required, the thickness thereof is reduced, thus producing a small-sized laminated inductor **41**.

The coil conductors **63–66** of the high permeability coil section **78** eliminate low-frequency noises, and the coil conductors **67–71** of the low permeability coil section **79** eliminate high-frequency noises. Because the winding direction of the coil conductors **63–66** of the high permeability coil section **78**, and the winding direction of the coil conductors **67–71** of the low permeability coil section **79** are opposite to each other, the magnetic field H**1** produced in the high permeability coil section **78** and the magnetic field H**2** produced in the low permeability coil section **79** do not cause mutual interference. Therefore, the impedance characteristic of the high permeability coil section **78** and the impedance characteristic of the low permeability coil section **79** respectively function independently. Consequently, the high permeability coil section **78** exhibits a sufficient low-frequency noise removal effect, and the low permeability coil section **79** exhibits a sufficient high-frequency noise removal effect.

The impedance characteristic between the external electrodes **81** and **82** of the laminated type inductor **41** is shown in FIG. **4** (see solid line **87**). In FIG. **4**, a broken line **85** shows the impedance characteristic of the high permeability coil section **78**. A broken line **86** shows the impedance characteristic of the low permeability coil section **79**. The solid line **87** shows that the increase of the impedance is suppressed in the intermediate frequency band (indicated by circle A in FIG. **4**). This is because the magnetic fields H**1** and H**2** respectively generated in the high and low permeability coil sections **78** and **79** repel mutually near the boundary of the high permeability coil section **78** and the low permeability coil section **79**, and both the leakage of the magnetic field H**1** to the low permeability coil section **79** and the leakage of the magnetic field H**2** to the high permeability coil section **78** are minimized. For comparison, a dashed line **88** shows an impedance characteristic of a laminated type inductor in which the winding direction of the coil conductors **63–66** of the high permeability coil section **78**, and the winding direction of the coil conductors **6–71** of the low permeability coil section **79** are arranged in the same direction.

In addition, the laminated type inductor according to preferred embodiments of the present invention is not limited to the above-described preferred embodiment, and various modifications are possible within the scope of the present invention. For example, the number of windings of the spiral coil, the shape of the coil conductor, or other features are modified in accordance with the characteristics of the product.

Furthermore, after stacking the magnetic sheets on which the coil conductors are respectively provided, the magnetic sheets of the above-mentioned embodiment are integrally baked. However, the present invention is not necessarily limited to this manufacturing process. For example, the magnetic sheets which are baked in advance may be used. Moreover, the inductor may be produced by the manufacturing method explained below. After forming a magnetic layer with a magnetic material paste by printing method or other suitable method, a conductive material paste is applied on the surface of the magnetic layer to form a coil conductor. Next, another magnetic material paste is applied on the coil conductor to define the magnetic layer in which the coil conductor is provided. Similarly, the conductive paste and the magnetic paste are applied in sequence alternately and repeatedly, while electrically connecting each of the coil conductors, whereby the inductor having the lamination structure is obtained.

As is clear from the above description, according to preferred embodiments of the present invention, since the low permeability coil section and the high permeability coil section are directly bonded together, and both of them are made of magnetic materials, the bonding property is excellent.

Since the high permeability coil section and the low permeability coil section are stacked without interposing the intermediate section made of dielectric material therebetween, a very small-sized laminated inductor is obtained.

Since the winding direction of the conductors of the low permeability coil section, and the winding direction of the conductors of the high permeability coil section are arranged opposite to each other, the magnetic field generated in the low permeability coil section and the magnetic field generated in the high permeability coil section do not cause mutual interference.

Therefore, the impedance characteristic of the high permeability coil section and the impedance characteristic of the low permeability coil section respectively work independently.

Consequently, the high permeability coil section exhibits a sufficient low-frequency noise removal effect, and the low permeability coil section exhibits a sufficient high-frequency noise removal effect.

While preferred embodiments of the invention have been disclosed, various modes of carrying out the principles

disclosed herein are contemplated as being within the scope of the following claims. Therefore, it is understood that the scope of the invention is not to be limited except as otherwise set forth

What is claimed is:

1. A laminated type inductor comprising:

a low permeability coil section in which magnetic layers made of a relatively low permeability material and first coil conductors are laminated in a vertical stacking direction; and

a high permeability coil section in which magnetic layers made of a relatively high permeability material and second coil conductors are laminated in said vertical stacking direction; wherein

the low permeability coil section and the high permeability coil section are laminated such that the first coil conductors of the low permeability coil section and the second coil conductors of the high permeability coil section are electrically connected in series to define a spiral coil, and the winding direction of the first coil conductors in the low permeability coil section and the winding direction of the second coil conductors in the high permeability coil section are arranged to be opposite to each other; and

in each of the high permeability section and the low permeability section, the first coil conductors and the second coil conductors are spaced from each other in said vertical stacking direction, adjacent pairs of the first coil conductors in said vertical stacking direction have substantially the same configuration and mutually opposite winding directions, and adjacent pairs of the second coil conductors in said vertical stacking direction have substantially the same configuration and mutually opposite winding directions.

2. The laminated type inductor according to claim **1**, wherein the low permeability coil section and the high permeability section are laminated directly together.

3. The laminated type inductor according to claim **1**, wherein the low permeability coil section and the high permeability section are baked integrally together.

4. The laminated type inductor according to claim **1**, wherein the low permeability coil section and the high permeability section are all made of a magnetic material.

5. The laminated type inductor according to claim **1**, wherein the magnetic layers of the low permeability coil section are made of paste containing ferrite powder of low permeability.

6. The laminated type inductor according to claim **1**, wherein the magnetic layers of the high permeability coil section are made of paste containing ferrite powder of high permeability.

7. The laminated type inductor according to claim **1**, wherein the low permeability coil section and the high permeability coil section are provided in a multilayer body.

8. The laminated type inductor according to claim **1**, further comprising external electrodes provided on the right and left end surfaces of the multilayer body.

9. The laminated type inductor according to claim **1**, wherein the coil conductors of the high permeability coil section are arranged to eliminate low-frequency noises, and the coil conductors of the low permeability coil section are arranged to eliminate high-frequency noises.

10. The laminated type inductor according to claim **1**, wherein the high permeability coil section and the low permeability coil section are stacked without interposing an intermediate section made of dielectric material therebetween.

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